

Space Shuttle Main Engine

- Extra Large Throat Main Combustion Chamber
- Robust Nozzle
- Advanced Health Management System

External Tank

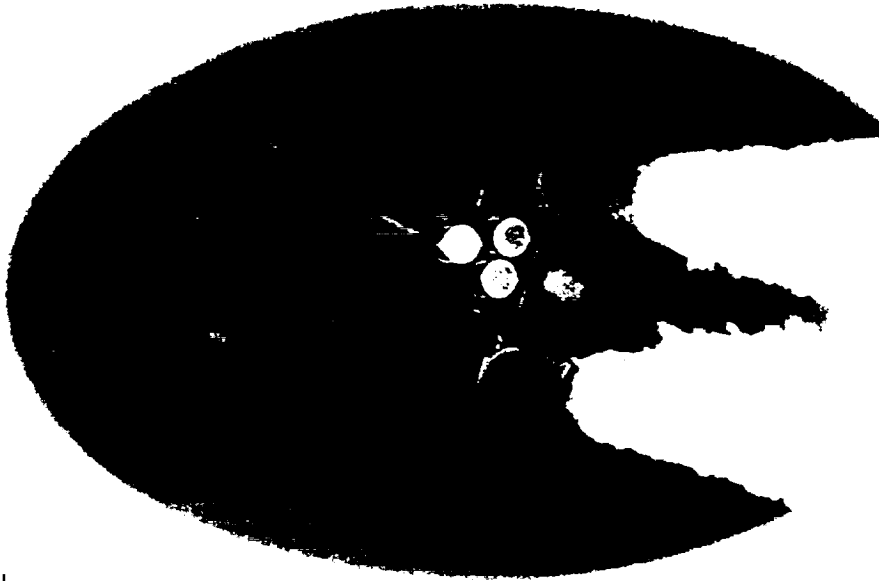
- Friction Stir Welding

Solid Rocket Booster

- Advanced Thrust Vector Control
- Attach/Holddown Hardware

Reusable Solid Rocket Motor

- Propellant Grain Geometry



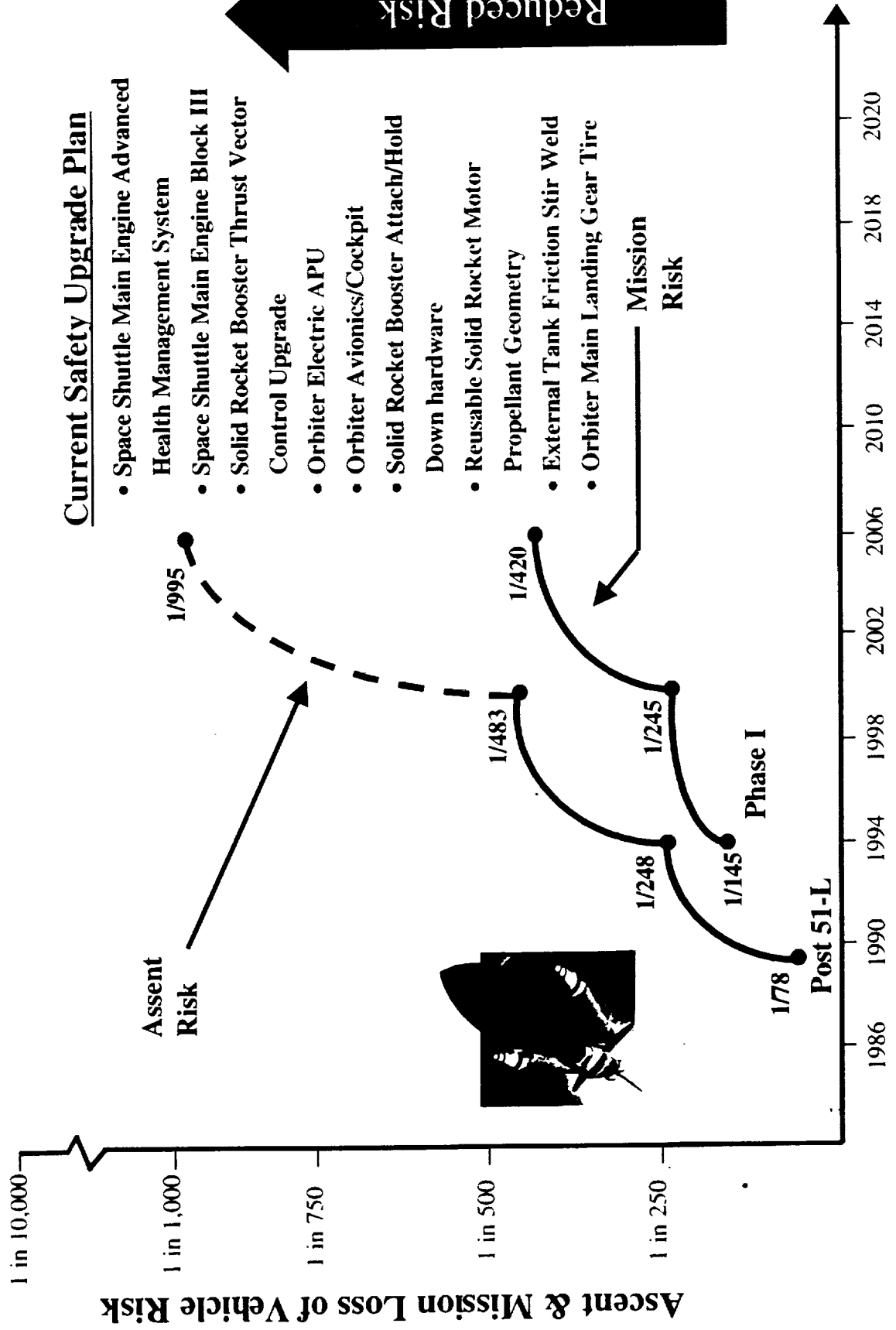
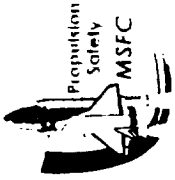
Space Shuttle Propulsion Safety Upgrades

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Space Shuttle Projects Office

May, 2000



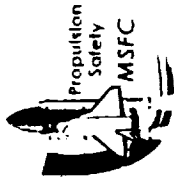
Safety Benefit of Proposed Shuttle Safety Upgrades



Increased Safety Through Selected Upgrades



Proposed Upgrades Reduce Significant Hazards



• Significant hazard reduction opportunities

- Crew cockpit situational awareness
- Orbiter hydrazine APU
- SRB hydrazine APU
- SSME critical failure modes

• Other hazard reduction opportunities

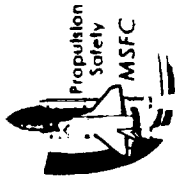
- Orbiter main landing gear tire & wheel
- RSRM propellant grain factor of safety
- External tank (ET) weld process reliability
- SRB Attach/Hold Down Hardware

• Studies

- Crew escape improvements
- Abort improvements
- TPS improvements
- Toxic processing protective gear



Space Shuttle *Safety* Upgrades



The Goals & The Challenges

● Goals

- Major reduction in ascent catastrophic risk
- Significant reduction in orbital & entry system catastrophic failure risk
- Improve crew cockpit situational awareness for managing critical operational situations

● Challenges

- All upgrades fully operational by end of 2005
- No impact to on-going operations
- Control costs to estimates provided in President's proposed budget

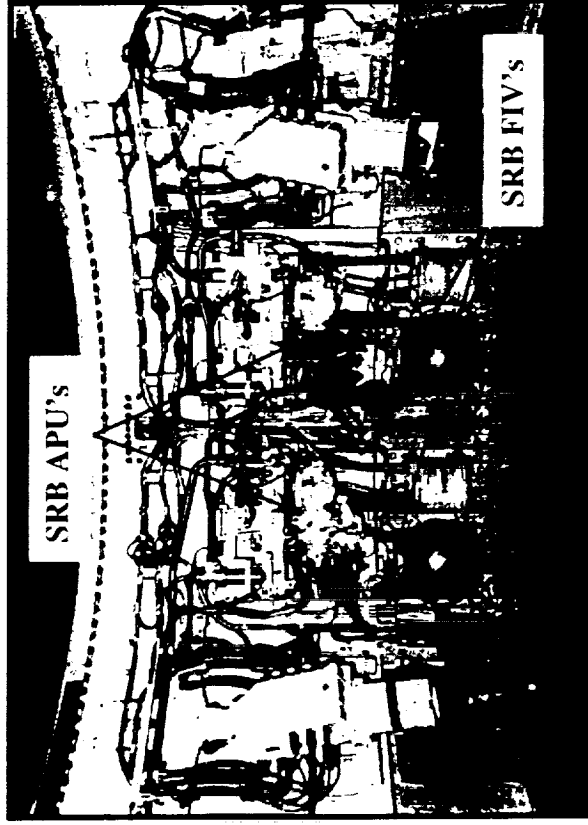


Propulsion Safety Upgrades Advanced Thrust Vector Control



Major Risk Factor

- SRB TVC System
 - Approximately 35 percent of total SRB risk
 - Approximately 7.5 percent of total vehicle risk



Inherent Hazards

- Hydrazine Fuel
 - Associated with ~50 percent of SRB TVC Criticality 1 failure modes
 - Personnel hazards and costs associated with handling

What

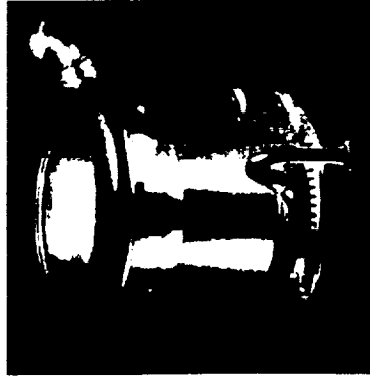
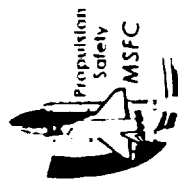
- Replace existing hydrazine APU

Why

- Reduce risk associated with personnel hazards and enhance safety by eliminating hydrazine



Propulsion Safety Upgrades Space Shuttle Main Engine BLK III



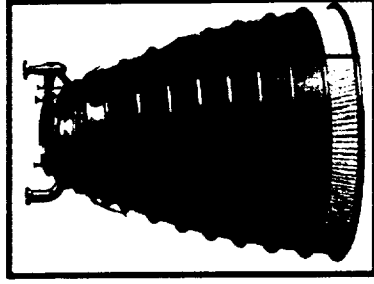
What

- X-large Throat Main Combustion Chamber (XLTMCC) reduces operating environment for turbopumps and other components for increased engine reliability
- XLTMCC is longer to optimize MCC/Nozzle configuration

Why

Safety & Reliability:

- Improve 3-engine catastrophic failure from 1 in 1,885 to 1/2,586 by reducing the operating environment



What

- Channel-wall constructed 2-pass nozzle
- Eliminates feedline/aft manifold crit 1 welds
- Robust fabrication with reduced part count

Why

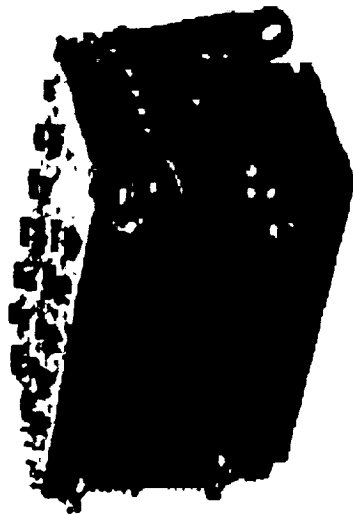
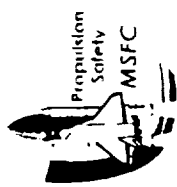
Safety & Reliability:

- Simplified construction
- Improves 3-engine failure from 1 in 2,363 to 1 in 2,593 and reduces nozzle failure from 1 in 13,860 to 1 in 27,720

Block III upgrade will result in significant engine reliability improvement



Propulsion Safety Upgrades Advanced Health Management System



What

AHMS Phase I adds the following to the existing SSME Block II Controller:

- High pressure turbopump vibration redline capability
- External high speed serial data interface

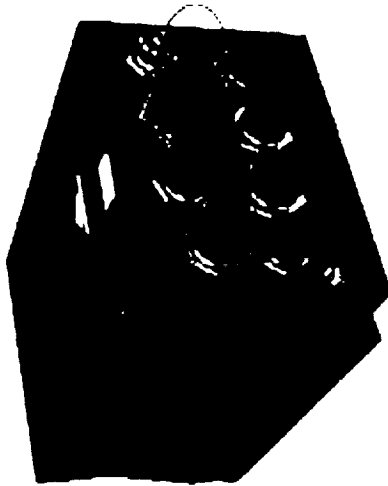
Why

Safety & Reliability:

- Reduces SSME ascent failure probability from 1/1283 to 1/1668

Future Development:

- High speed serial data interface supports development of AHMS Phase II



What

AHMS Phase II provides the capability to detect and isolate engine failures with high confidence and provides previously unavailable mitigation options

- Phase IIA - Health Management Computer (HMC), Optical Plume Anomaly Detection (OPAD) and Linear Engine Model (LEM) prototyping and requirements definition tasks
- Phase IIB - development of Health Management Computer (HMC) as real time flight system, production, integration into Orbiter fleet

Why

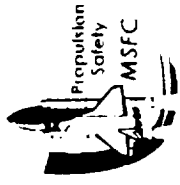
Safety & Reliability:

- Further reduces SSME ascent failure probability from 1/1668 to 1/2189

AHMS upgrade will result in significant engine reliability improvement



Propulsion Safety Upgrades Friction Stir Welding



LO₂ Barrel Welds (OB)
4 each 8-foot long
Tapered Thickness
(0.500 - 0.425 - 0.387)

LH₂ Barrel 1 (Longeron Welds)
4 each 15-foot long
Tapered Thickness
(0.650/0.550 - 0.320)

**Barrel
Welds**
8,000 inches
out of
36,000 total
inches



LH₂ Barrels 2, 3, and 4 Welds
24 each 20-foot long
22 each constant thickness (0.320)
2 each Tapered Thickness (0.500 - 0.320)

LH₂ Barrel 1 Welds (HB1)
6 each 15-foot long
Constant Thickness (0.320)

What

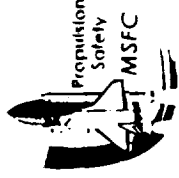
- Refine the technology to replace longitudinal fusion welds with friction stir welding
- Replace existing tools with two new universal FSW tools
- Implement friction stir welding on the longitudinal welds for the oxygen and hydrogen barrels

Why

- Improved mechanical properties
- Reduced defect rate
- Increased process control



Propellant Grain Geometry Modifications

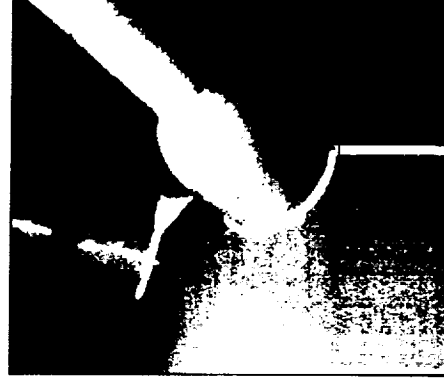
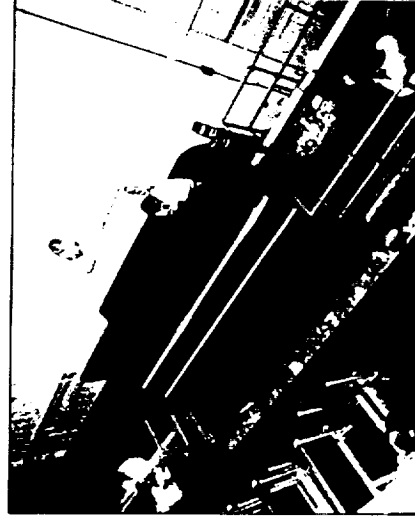


- **Objective**

- *IMPROVE System Safety AND Personnel Safety* by modifying propellant grain geometry to improve structural factors of safety
 - Potential system risks; over pressurization and premature flame at case wall
 - Personnel risk; exposure to hazardous operations

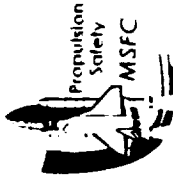
- **Background**

- CEI specification structural requirements for propellant grain are below a 2.0 safety factor due to localized induced loads. Five regions exist: 1. Transition area (transportation 1.4); 2a. S-bend (storage 1.4), 2b. S-bend (launch 1.6); 3a. Igniter Boot (storage 1.4), 3b. Igniter Boot (launch 1.6); 4. Fin Tip (storage 1.4); 5. Fwd & CTR Flap Terminus (storage 1.4)





Propulsion Safety Upgrades Summary



Safety Is Our #1 Priority

Strong Program/Project Management Initiatives

Highly Motivated TEAM